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Edited by

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THE TEA RESEARCH INSTITUTE.
St. Coombs, Talawakelle.

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LIFE AND DEATH

DR. C. H. GADD

How long should a tea bush live? This question, which often arises when the future treatment of old tea areas is discussed, is based on the view that to every species, animal and plant, is allotted a limited span of years, and, as that period expires, death follows as a natural consequence. By 'death from old age' is meant death resulting from inner causes connected with ageing, and *not* from accidental causes external to the species. Accidental death may occur at any time as a result of pests, parasitic diseases or physical violence; but natural death, the consequence of senescence, must occur at the end of a more or less definite period, the life span of the species. Youth, maturity, senescence is the usual sequence in animals, but do plants, and the tea bush in particular, pass through similar stages terminating with death due to old age?

Horticulturists classify their plants as annuals, biennials and perennials, but these categories, though convenient, are not so clear cut as their names suggest. An *annual* is usually defined as one which lasts for a year only, though the life span of many, from seed germination to seed shedding and death, may be but a few weeks, while others may live for more than a year, particularly if flowering is prevented. *Biennials* normally live for two years; in the first, they accumulate stores of food to be expended during the second in production of flowers and fruits. Occasionally, a biennial may flower or fruit in its first season, *e.g.*, beetroot, when it is said to 'bolt.' The main characteristic of both annuals and biennials is that the plants die soon after fruiting. This suggests a connection between fruiting, or sexual reproduction, and death — as though all the vital resources of the parents are poured into the seed to ensure the propagation of the species. A similar connection between sexual reproduction and death exists also in the animal world. A moth or butterfly after emerging from the chrysalis in all the glory of its new body may live for a few days only, during which time it mates and lays eggs. Reproduction is its life's climax.

Perennials persist for indefinite periods. The American giant redwoods (*Sequoia gigantea*) are known to have survived more than 2,000 years, but no tea planter expects his bushes ever to approximate that age. Some perennials behave like annuals in that death occurs after first fruiting. The talipot palm (*Corypha umbraculifera*) for instance, may live for 50 years or more and then, for no apparent reason, it bursts into flower and dies, almost before the fruits are ripe. The great majority of perennials, however, reproduce their kind annually without fatal consequences. Their ability to propagate is regarded as indicative more of vitality and vigour than of senescence and approaching death. In such perennials there can be no connection between sexual reproduction and natural death; which merely goes to show that there is no one universal law of mortality.

The period of useful existence of a machine is sometimes termed its 'life.' A

new motor car usually requires little more than a periodic tightening of a few nuts and other minor adjustments at first, but later, as it grows older, parts begin to wear, necessary replacements and repairs become more and more numerous until at last, in its old age, upkeep becomes uneconomic and the car is relegated to the scrap heap. The length of its life depends upon several things — its make or design (Ford v. Rolls Royce), the care and maintenance it has received, and the rate and mileage it has been driven.

Nature in some instances seems to act in much the same manner as the car owner. Throughout life, repairs and replacements have to be made to the body, and with the passage of time the upkeep problem becomes more and more difficult, till at last the effort towards maintenance is abandoned and life ceases. The length of life of an organism seems to depend upon factors corresponding fairly closely to those affecting the car — its species (make), its ability to regenerate parts (maintenance) and its rate of living (mileage and speed).

What are the repairs and replacements a living organism is required to make? Some replacements are well known. A snake casts off its old skin; the deer sheds its horns; a tree drops its leaves; and a tea bush has to make good the ravages of plucker and pruner. Such lost parts are replaced by new ones. Other, but much less obvious repairs also have to be made. We know that when respiration has ceased, if only for a few minutes, the human body is dead. Respiration is one of the signs of life; it is indicative of one of the many chemical changes continuously occurring within all living tissues. The exhaled carbon-dioxide results from a destructive change, a breaking down of complex molecules into simpler forms, some of which, like the carbon-dioxide itself, are waste products and must be got rid of. Such destruction necessitates rebuilding and repair. Throughout life these processes, destruction and repair, are continuous; they are so complex that one may well wonder, not so much why life has a limited span, as why it survives at all. Efficiency in getting rid of waste products and in executing repairs may well be deciding factors in determining the span of life.

The basic unit of biological matter is termed a *cell*. It is usually of microscopic size, and consists of a cell wall or membrane within which is the slimy, living substance, *protoplasm*, a part of which forms a denser sphere known as the *nucleus*. This basic structure and the one living substance, protoplasm, are common to all forms of living organisms, plant or animal, large and small.

The smallest living things consist solely of one cell, capable of independent existence. Though microscopic in size they have the longest lives; in fact they have been claimed to be potentially immortal. One of their most notable characteristics is an ability to transform each body into two new ones. It is as though an old motor car transformed itself more or less suddenly into two brand-new, unworn cars of the same make and pattern, with the worn parts of the old one only going into the making. First, a constriction encircles the one-celled body about its middle; the constriction deepens and ultimately divides the body into two equal parts. Finally, the two halves separate and each grows until it attains the size of the original. Under favourable conditions the whole process may take less than half-an-hour, and may be repeated an indefinite number of times. Each time it happens the older organism is replaced by two young ones; but there is no death and no corpse. The process is

obviously a method of reproduction in which sex plays no part.

Bacteria are a group of unicellular organisms having this ability to 'multiply by division.' When growing on a solid substance they do not migrate but remain where they were formed, more or less in a heap, termed a *colony*. Although one bacterium is invisible to the naked eye, the colony it forms is easily seen after a few days' growth, if conditions, including food supply, are favourable. The growth of the colony is not due to an increase in size of the individuals but to an increase in numbers, and it is continuous so long as food is available, and accidents are avoided. But for the limitation of food there appear no very obvious reasons why certain species do not cover the world. Bacteria are well known as germs which cause serious disease; a few do, but the great majority do not.

Other well-known microbes are the fungi. Some cause disease in plants, others (mushrooms) are edible, and many (moulds and mildews) grow in all sorts of unwanted places. The 'body' of a fungus is usually a microscopically-fine thread, termed a *hypha*, which grows by increase in length and by repeated formation of lateral branches. The felt-like mass formed by much branched hyphae is termed a *mycelium*. Growth in length of filamentous fungi occurs at the apex of each hypha. The terminal cell divides transversely, never lengthwise, but instead of the two halves separating, as with bacteria, they remain attached, separated only by a thin wall, and each grows to normal size. In some fungi the dividing walls are suppressed; then the mycelium consists of a single, much-branched, undivided thread containing many nuclei. In a laboratory fungi are frequently grown on plates (petri dishes) containing a solidified nutrient medium. If growth is not interfered with, the fungus forms a circular mycelium, the diameter of the circle steadily increasing till the plate is filled. Small pieces of mycelium transferred to fresh plates grow in like manner; there appears to be no limit to the number of plates which can be filled by one fungus, nor to the time growth can be continued.

Good examples of the unlimited growth of fungi are to be seen in the 'fairy rings' of dark-green grass in poor pastures. Early literature is filled with tales of superstition concerning them, such as, that they marked the paths of dancing fairies, and that they marked places of treasure which could be secured only with the aid of fairies or witches. That supernatural influence brought about their formation was a common belief until scientists gave a less fanciful account of them. Now, it is known that 'fairy rings' indicate the progress in growth of a fungus through the soil. The annual increment in the diameter of the ring is indicative of the rate of growth of the fungus, and so affords a means of estimating its age. Such estimates can only be approximate because the annual rate of enlargement of the ring, *i.e.*, the rate of advance of the fungus, depends upon climatic conditions. In dry years little or no growth may be made, whereas in others, more favourable, an appreciable advance may occur. Some of the largest rings in Colorado (Shantz and Piemeisel 1917) are over 650 feet in diameter, and have been estimated to be more than 400 years old. A fungus with such a body can hardly be regarded as a microbe; it is one of the largest and oldest living things.

It must not be imagined that the earth within the fairy ring is filled with the body of the fungus. In the centre, the mycelium has long been dead and has disappeared through decay. The only living part is usually just outside the ring of dark-green

grass — dark-green, because the grass is stimulated by the release of plant nutrients from the decaying mycelium. But so long as the fungus remains alive at its periphery it grows ever outwards and never doubles back on its track. Its maintenance problem is solved by complete replacement and not by repair.

Something akin to fairy rings may be seen in tea fields where the fungus *Poria hypolateritia*, travelling slowly through the soil, kills the bushes in its path to obtain from their roots a food supply necessary for further advance. The progress of the fungus is marked not by the greenery of stimulated growth but by the ever-increasing number of its victims.

The phenomenon of unlimited growth appears to be a key to long life, if not immortality. It seems immaterial whether the growth is exhibited by increase in numbers, *non-sexually* as in bacteria, or by increase in size as in fungi.

Many plants, more perhaps than is generally recognised, exhibit this phenomenon of unlimited growth and horticulturists make use of it whenever vegetative propagation is employed. Vegetative propagation, as opposed to propagation by seed, is essential whenever plants of exactly similar characteristics are required. By dividing a plant into separate portions and culturing each part under suitable conditions, a number of plants exactly like the original may be obtained. These new plants are but severed parts of the same individual and have the same characteristics. For this reason fruit trees and many other plants are almost invariably propagated vegetatively. The tea planter still propagates from seed, and consequently, in tea fields the bushes are as unlike as the men of any town. Such variability is the normal result of sexual reproduction. Yet there is no reason why whole tea fields should not be covered by the severed parts of one bush, nor why all the leaf for a whole day's manufacture should not be obtained from one (much divided) bush, if it be desired.

If a part of a shoot is removed from a tea bush and planted in the ground the cutting will put out its own roots and continue to grow. The bush from which the shoot was removed will replace the lost part, much as a lizard will grow a new tail after losing its original. The removed shoot also will replace its lost parts by forming roots ; but it would be 'news' if the lizard's discarded tail replaced the lizard. The cutting ultimately becomes a tea bush with exactly the same characters as the one from which it was taken. In fact it is still the same bush. Had the shoot not been removed it would have continued to grow, though certainly not to the same extent ; that it was removed and put into the ground may be regarded as accidental. The area occupied by any one bush may be extended tremendously by means of cuttings, and provided that man occasionally performs the 'accident' of removing and planting a few shoots in suitable ground, there appears no reason why the selected bush should not survive as long as human life exists.

A tree exhibits continuous growth in other ways than by its ability to reproduce itself from cuttings. When its leaves grow old they are shed and replaced later by new foliage. The leaves decay, as the old mycelium within the fairy rings decays. What is not so obvious is that when the old leaves are replaced by new ones, the tissues which supplied them with water and which carried away the results of the leaves' activities are also replaced by new ones. We need here consider only one such tissue, the wood through which water is conveyed from the

soil to the leaves. As a tree unfolds its new leaves, it also lays down new tissues to serve them (Priestley 1935). A newly-erected house in a town would be connected to the nearest existing water main; but each new leaf is provided with new pipelines extending to the source of its water supply, the soil. These new pipelines (wood) are formed on the surface of the existing woody cylinder, which in consequence increases in girth annually. Like a fairy ring, a tree grows ever outwards while the older tissues within die progressively. The age of any one part is much less than the age of the tree as a whole; the shoots plucked from a bush may be but a few weeks old whereas the age of the bush as a whole must be measured in years.

Wood, besides conducting water, has another function; it gives the tree mechanical strength to withstand storms. Unlike the fungus of a fairy ring, which has no further use for any of its dead parts, the tree must maintain its dead wood unweakened by decay to give stability. Protection against decay is provided by an unbroken covering of living tissues which entirely encloses the dead wood. A single hole in that protective sheath will let in the external agencies of decay, and begin the weakening of the timber. One injury may do little damage, but as injury succeeds injury the results are cumulative; the tree weakens, the trunk becomes hollow, and a limit is set to the length of its life. That limit is determined largely by the durability of the wood. The holes in the protecting sheath of living tissue may be caused by gales, or knives, by insects or other parasitic organisms — all are external agencies and largely preventable.

The tea bush is one of the most maltreated of trees. Its young shoots are pinched back (plucked) every week or ten days, and its branches are pruned severely every few years. Such wounds, holes in the bush's protective armour, appear necessary if the tea industry is to survive; but it is equally true that the survival of bushes depends upon their ill-effects being reduced to a minimum. This point of view is sometimes lost sight of when pruning estimates are under consideration. No single cultural operation can shorten a bush's expectation of life as effectively as bad pruning.

Mention was made earlier of the rate of living being a factor possibly affecting length of life. By rate of living is meant the time rate at which all vital processes, such as respiration, growth, sexual activity, etc., proceed. Temperature materially affects the rate of these activities. At lower temperatures, as in the hill country, tea grows less rapidly than at lower altitudes with higher mean temperatures, and consequently the bushes should age more slowly and live longer at the higher elevations. From experience one knows that the expectation of life of up-country bushes is certainly greater than of low-country bushes, but, in the writer's opinion, that is attributable less to the difference in the rates of living of the tea bushes themselves than to the different rates at which decay progresses at the different elevations. Old age in tea bushes is perhaps better measured by the amount of decay in their woody frames than by their years.

If the phenomenon of unlimited growth is truly a key to long life, the tea bush appears to have possession of it so long as it is *not* allowed to grow unhindered. If left unmolested, unplucked and unpruned it soon attains its maximum height and spread. Its height rarely exceeds 25 feet and no method of increasing it is known. But by suitable pruning the bush may be induced to increase its spread and to form a plucking table, in exceptional cases, with

a diameter of 24 feet (Ukers, W.H. 1935). In a natural state definite limits are set to every tree's size. Increasing size brings with it increasing difficulties in transport, not only of water, but of all other materials, food and waste products, which have to be moved from one part to another. One view of the cause of senescence in animals is that it results, at least in part, from chronic poisoning of the organism by some of the waste products of life processes which the animal is unable to get rid of. Whether trees of maximum size suffer from similar disability, when transport of materials within them becomes difficult, is open to doubt. The long life of Giant Sequoias already mentioned does not suggest this to be the case, and no very strong evidence has yet been brought forward to show that trees exhibit a senescence comparable with that well known in animals.

A brief answer may now be given to the question with which this article opened. Given a constant supply of food, air and water, shelter from storm, and protection against its numerous enemies, there is no apparent reason why a tea bush should not live for ever. In short the length of its life will depend on the environment.

That a tea bush is potentially immortal may be only of academic interest; it certainly would not be an economic proposition to attempt to prove the theory in practice. The amount of protection which can be given to a crop is determined by the cash return. Complete protection, if it could be achieved, would probably prove to be mere extravagance; failure to provide any is assuredly false economy. Between the two extremes lies the road to agricultural success.

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VEGETATIVE REPRODUCTION

E. C. MARSH-SMITH *

These notes are written in the hope that others may be encouraged to try the system, and that improved methods may be found by them. Interest in vegetative reproduction has been reawakened by the return to more normal working conditions, by the realization that some form of improved material must be used in planting, and by the return of those whose early work at selection was cut short by the war. The writer first attempted vegetative reproduction in 1933-34 by using layering and marcotting processes, and finally by using leaf shoots. Only the last-named proved of any value, but the results were so poor, working under estate nursery conditions, that all further attempts were given up till 1938. The experiments at the Tea Research Institute gave encouragement for further trials.

SELECTION OF BUSHES

The method of selection employed was to choose by eye those bushes that appeared to be suitable from the point of view of jat, spreading habit, and closest plucking points. All selected bushes were at first taken in one field of good jat tea, but growing among rocks, and not in very good soil. The original purpose was to select for seed-bearers, and so locality had to be taken into consideration. Selected bushes were surrounded by good jat tea. The bushes were plucked for ten rounds at ten-day intervals in the period of December, 1938 to March, 1939, and were split into three groups, each of a distinctive leaf type. Some further test-plucking was carried out at later dates to test for consistency of yield.

On the basis of yields the three types, now called DSB1, DSB2 and DSB3, were placed in that order, and gave yields of made tea per bush of 18 oz., 20 oz. and 41 oz. per annum. The champion bush gave 56½ oz. and was type DSB2. The lowest from any bush was 11 oz. All were plucked by the same plucker each time, overlooked by a kanakkapillai. The maximum yielder had a very strong spreading habit, close set plucking points, and a very long type of leaf. The other two types were very broad leaf and medium broad leaf. In all cases the yield not only varied with the size of the bush, but also with the density of the plucking points. The champion bush was not the largest. Reselection was then carried out reducing the original 157 to 30. It was found that after studying hundreds of bushes for yield and type, it became possible to select good yielders by eye, without much risk of failure. This procedure was finally used in the selection of 394 bushes for growth as seed-bearers, which are now in bearing (1946). It is proposed to reduce this number to about 200 owing to the need for thinning-out, and spacing, and for rejecting a few that have not lived up to the promise of their early appearance.

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1,800 to 2,400 done by the team of three, in one day. Cuttings made ready in the morning should not be used in the afternoon. Therefore prepare only such amount as one can manage each period. The beds should not be more than 3½ ft. wide, but any length to suit the site. Plenty of space is required to work between the beds. Thus in any large nursery quite 25 per cent space is taken up by paths and working space.

Taking the contour system as likely to be the normal, at 5,000 to 6,000 bushes per acre, it will be realised that a very large nursery and considerable preliminary work is needed. From 4 and 5-year-old clonal bushes up to 40 leaf cuttings have been taken per bush. From large selected 'parent' bushes, after pruning, one may get well over 150. The record clonal bush here gives several hundred. These figures are from tippings taken from 3 to 4 months or so from pruning. From old bushes in plucking it is difficult to get sufficient cuttings unless the bushes are allowed to run up first. For anyone proposing to plant up any acreage beyond a small experimental plot, it would be advisable to set 40 per cent more cuttings than bushes per acre required.

PLANTING OUT

It takes from a matter of weeks to several months for the leaf cuttings to grow ample roots. When set with sprouting buds or young shoots leaf cuttings often appear as if they must have rooted, but on examination only a callus is found on the butt-end of the stalk. When rootlets are forming they appear as whitish spots on the lip of the callus, and gradually develop into a mass of white hairlike roots. The better the root system the more likely is a leaf cutting to be successful. In hundreds of experiments the writer has found it advisable to give a longer rather than a shorter time for the development of a good root system. The different parent bushes will give very different results, and so each type should be planted separately, and clearly marked with its individual clonal name or number. To test for root development it would be advisable for anyone new to the work to take up one or two leaf-cuttings of each type at various stages, say, from two months or so onwards, from setting. Experience will soon be gained as to rate of development, and the variations noted. A special book should be kept for dates of planting the different types and the results.

If the parent leaf dies before roots develop, the stalk will die. Dying leaves may be noted by their speckly appearance, or later by their dried up condition. There is no hurry to remove these. The parent leaf should never be removed from the stalk. Nature will discard the leaf in due time.

After removal from the bed the rooted cutting should be set in a basket such as is used for small tea plants, preferably the stalk-ended basket, which can the more easily be set firmly in another bed. After a few weeks, say, three to six weeks, the basket plants will be rooting in the new soil of the basket, and can be hardened off by thinning the shelter. This will depend on the climate.

From the time of pruning the selected parent bush to planting out the progeny in the field will take six or more probably eight months (in Dimbula). Some types are even slower. It is all the more necessary to get a quick striking type of parent bush. It will also be found that such a type gives a fast growing progeny. In 4 years a large healthy bush can be formed. It will also be noted that these young

bushes when pruned recover remarkably. From YF6 (Clonal bush), progeny 5 years old are ready for tipping 60 to 70 days after pruning, as against 90 or more of the young replanted areas from seed.

As the rubber planter can note at a glance the difference between such clones as T.J. 16 and B.D. 5, so will the marked evenness and peculiarities of the parent bushes be seen in the progeny produced by vegetative reproduction of tea.

SOME RESULTS FROM EARLIER WORK

Some figures of results may be of interest to show that at least on a small scale practical results can be attained until experience allows large scale work.

At first several hundred cuttings had been experimented with to study formation of callus and roots, style and rate of development, etc. One type YF6 was so successful that no further work was done. But of the better jats 651 cuttings were set to select more types. The results they gave in 1939 were :—

Set	June-July	DSBI	168
		DSB2	212
		DSB3	271
			651
Successes set in baskets —			
	September		286
	October		239
Still in nursery (end of 1939)			103
Failures			23
			651

The general average of success showed that these three types are good. The experiment ended with the declaration of war, and those marked as still in the nursery were gradually planted out. Many of them died. The total loss was 90 out of 651, giving some 75 per cent success. Some of the earlier ones and those from clone YF6 were planted out in a poor soil area and are now well grown and in bearing. The remainder were used to supply *Poria* plots.

It would be advisable to start in a moderate way and work out one's own technique as locality and variable estate conditions would much affect results. Probably a 30 per cent success could be envisaged from ordinary estate nursery methods, with 60 per cent when more experience is gained.

To summarise, first make sure of the parent materials to be used by seeing that the bushes qualify under the headings given in the previous paragraphs. Next make sure of the propensity to strike and grow rapidly. Once this is assured get the characters of the made tea defined. There would then only remain the improvement of one's technique to ensure a big output for practical purposes. Any slow striking and weak parent types should be ruthlessly discarded, as the work would only become laborious and unprofitable.

PRUNING TODAY

F. R. TUBBS

The conception that pruning has a restorative or invigorating effect upon the bush dies very hard. There are, after all, superficial appearances of such an effect in any field recovering from pruning. Rapidly growing shoots are produced in profusion irrespective of season, the leaves are large and sappy, and the general effect is one of vigorous reaction to the stimulus applied. It may be easy to suggest that the greater the stimulus the more effective the results, or that weaker bushes require more severe pruning to stimulate them adequately, but the result of converting such theory to practice is too often the subsequent despatch of unthrifty bushes to St. Coombs, with a request for diagnosis of the trouble. Such bushes have frequently a greatly reduced frame, bearing a few spindly branches; nothing but the massive central stem and root stock remain to show that it was once a sound and vigorous bush.

Since normal healthy tea grows vigorously in fertile soil of suitable acidity under our local conditions, it is obvious that an unthrifty bush is one suffering from a pest or disease, is growing in unfavourable soil, or is incapable of vigorous growth owing to the accident of its genetical history. As none of these conditions can be cured by the knife or saw, it is apparent that heavy pruning of weak bushes is unjustifiable.

As time passes after pruning the growth of a normal bush, spread over an ever increasing number of branches, becomes more subject to seasonal variations in rate. In spite of the repetition of superficial prunings in the form of plucking, increased dispersion of growth and its liability to decrease markedly under unfavourable climatic conditions renders pruning economically desirable. As soon as this is carried out, growth is again concentrated into a relatively small and shallow zone, and a localised and deceptive impression of more rapid growth and enhanced vigour is given. The fact that a greater proportion of the total growth of the bush can then be removed for manufacture is the basis of the adoption of pruning as an economic necessity, but is no argument that pruning, from the point of view of the bush, is desirable or beneficial.

Nevertheless, more severe pruning than is really necessary to meet these economic requirements is only too frequent today and it is probable that Ceylon will suffer from the effects of one of its periodic waves of heavy pruning unless the need for such treatment is critically examined by all responsible for pruning policy. The reason adduced for heavy pruning may be "to remove snags and knots," "to remove woodrot," or some variant of "to kill or cure" phrased in gentler words. The two former are alone worthy of examination.

One way of removing snags, knots, and woodrot is to collar prune the bushes. As a result of such treatment new frames are produced which must result in better yields if there is any *economic* basis for the treatment. It is instructive to examine the results of an experiment on collar pruning at St. Coombs, which led trained observers to comment upon the vigour of the resulting growth and the excellent "wood" produced. What gain in yield, if any, resulted, or what was the price paid for this

pleasant impression of vigour and clean frames?

Two series, each of twenty plots of one hundred and twenty bushes, were respectively collar pruned and clean pruned in 1937. The collar pruned bushes came into plucking 15½ months later, compared to 5 months in the case of the clean pruned plots. The loss of crop during this period is estimated to be 783 lb. of made tea per acre. In addition the yield per acre during the 22 months that elapsed between the collar pruned plots coming into bearing and the next pruning of the plots was also reduced. The collar pruned area yielded 480 lb. per acre compared with 898 lb. per acre from the clean pruned plots. Nor was the loss confined to the first cycle alone, for in the first fourteen months of the next cycle the yields were 375 lb. and 590 lb. of made tea per acre respectively. At this point records were terminated owing to the war. Over the fifty-two months of the experiment the yield of the collar pruned plots amounted to only 38 per cent of the clean pruned plots.

It is difficult to argue from these data that the bushes had either been invigorated or improved by collar pruning. It was, therefore, of interest to determine whether the collar pruned bushes *subsequently* exhibited greater vigour than the clean pruned bushes. Measurements of the diameter of the plucking table were therefore made in September, 1946—9½ years after the commencement of the experiment. The average diameter of the collar pruned bushes was 41.6 inches and the clean pruned bushes 43.7 inches. The difference, though small, had a significance of over 100:1, and it is therefore evident that the collar pruned bushes had *still* not recovered from their treatment. It is of interest to note that the absence of snags, knots and woodrot in the new frames had not compensated for the damage done to the spread of the bushes.

There is nothing surprising about these results. The new growth produced in the form of shoots anywhere in a bush is accompaned by new growth throughout the frame, the new tissues serving as channels of movement of food and water to and from the shoots above. This takes place irrespective of knots or woodrot, and is the explanation of the occurrence, which may be observed in any fertile field, of bushes bearing thick new wood at the end of branches knotted where earlier wounds have callused over, and/or suffering from woodrot. Too often such branches are removed at the next pruning and the "removal of snags" is accompanied by the loss of branches capable of further usefulness. Such branches should only be removed when they are rendered redundant by the presence of younger and more vigorous branches in such a position that removal entails no reduction in the frame of the bush. Most serious consideration is desirable before saw work is advocated or permitted, although it is realised that labour conditions have also a practical bearing upon the policy actually adopted.

In concluding this advocacy of lighter, though not necessarily higher, pruning than is at present common up-country, reference may be made to other aspects of pruning. As a result of the tendency to cut into the frame of the bush to remove something unsightly, the number of "points" left on the pruned bush is drastically reduced. It is always preferable to prune to thin points than to produce a cupshaped frame of old branches with four or five lonely points on the perimeter. The gap has to be filled by secondaries and tertiaries from tipping shoots before any satisfactory yield is

obtained, and yield in the first year of the cycle is consequently unnecessarily restricted.

The second point is the encouragement of spread. It is the fact that there has been no noticeable improvement in the spread of up-country tea during the last ten or more years and, even more disappointing, the pruning in vogue ensures its reduction as regularly as ever. Wherever present, fringe branches should be left and it should be a standing rule that no lateral branch is cut back below the pruning level. The theory that such treatment results in the production of yet lower and more spreading branches is based on isolated successes only and takes no account of the more numerous cases where such treatment merely results in loss of spread.

Parallel to the lack of fringes in pruned fields up-country is the absence or insufficiency of the "lung" branches left on pruned bushes at lower elevations. The practical result of this is that more dead bushes, killed by pruning, are being received by the Institute than for years past. It is to be hoped that the need of an adequate leaf surface during recovery from pruning at the lower elevations will not be forgotten. Those interested will find full details in *Bulletin No. 15*, and in past volumes of the *Tea Quarterly*.

The reader will have noted more than one reference to the fertility of the soil in this article. It will have served its purpose if it emphasizes the fact that neither the knife nor the saw can, in any way, deputize for the manure bag.

STUDIES OF SHOT-HOLE BORER OF TEA

2—GALLERIES

DR. C. H. GADD

Many boring beetles, of which *Xyleborus fornicatus* is one, make tunnels, circular in section, in timbers. If the holes resemble those made by small shot, *i.e.*, anything larger than the equivalent of a pinprick up to 3 mm. in diameter, the beetles are commonly termed "shot-hole" borers. Many of them, including their young, do not eat the wood but feed on a fungus (the ambrosia) which grows on the walls of the tunnels ; such beetles are often termed "Ambrosia" beetles. The shot-hole borer of tea is also an ambrosia beetle. The majority of ambrosia beetles attack newly-felled trees, their liability to attack lasting for a relatively short time, till the sap dries out. The shot-hole borer of tea is an exception to this general rule as it attacks living stems, and in consequence has become an important tea pest in Ceylon.

If the making of tunnels in wood were the sole injury resulting from the beetle's activities, the pest in tea would be of little economic importance. The tunnels reduce the mechanical strength of the wood, with the result that infested branches tend to break rather easily during such operations as plucking, forking and pruning. The loss of branches during the plucking cycle results in loss of crop

though its amount is impossible to estimate accurately. Other damage, such as the dieback of pruned stems, can also be traced to the presence of galleries.

Places of Entry.—The entrance to a gallery (exit is by the same aperture) is seen as a small round hole, the shot-hole. Green (1903) first drew attention to the fact that the entrance is "usually at a leaf scar or immediately below a side shoot." Leaf scars can often be distinguished on tea stems even after the bud has developed into a lateral branch, and evidently, it is a matter of indifference to the beetle whether the bud has burst and grown into a stem or not at the time of entry. If, however, entry is made through the scar before the bud has grown, it is very unlikely that the bud will grow later. The reason for this statement is that although the bud itself is not damaged, the wood vessels through which water must pass to the bud to cause it to burst and grow, are usually severed during the boring. The failure of buds to break becomes of importance after pruning.

One method of demonstrating this preference of the tea borer is by counting the galleries in suitable branches and noting the numbers at the nodes and between them. More holes are found at the nodes than would be expected if the beetles entered the stem anywhere, haphazard. Experimentally, the beetles have been tested with suitable severed tea branches, the beetles being allowed to move freely and select their own places for entry. Of 43 beetles that started to make galleries 32 began boring at the nodes, usually through the leaf scars, and only 11 entered the internodes.

Gallery Formation.—The galleries are made by females soon after maturity and emergence from the parent gallery. Each begins with an entrance tunnel, which is invariably directed radially towards the centre of the stem. Later construction seems to depend largely upon the diameter of the stem.

The best known galleries in tea are those made in stems about half-an-inch in diameter or less as they are much more common, more easily dissected, and can be studied without completely destroying whole bushes in the process. In such stems Green (1903) described and illustrated two main types of gallery.

The first occurs mainly in stems about half-an-inch in diameter. In Green's words "The beetle first drives a straight tunnel almost through the branch but stopping just short of the other side. From the extremity of this tunnel it runs a circular gallery in an ascending spiral above and a similar gallery in a descending spiral below." The straight arm, or entrance gallery passes through the centre of the stem; either through the pith or slightly to one side of it, but always stops before the cambium on the far side is reached. From this end the circular branches follow the curvature of the woody cylinder very accurately: they often run very close to the external surface yet never touch it or damage the cambium.

The second type occurs in thinner twigs. Again in Green's words "A longitudinal tunnel may run down or up the pith for an inch or more before the construction of the spiral gallery." In its simplest form there is no circular arm, only a longitudinal gallery in the pith, (Fig. 5) but more frequently a gallery has both longitudinal and circular or spiral arms (Figs. 3 and 6).

Often the circular arms do not form a spiral, but run in the same plane as the entrance gallery, with the result that they return to the straight entrance gallery near to the entrance; but they always stop just

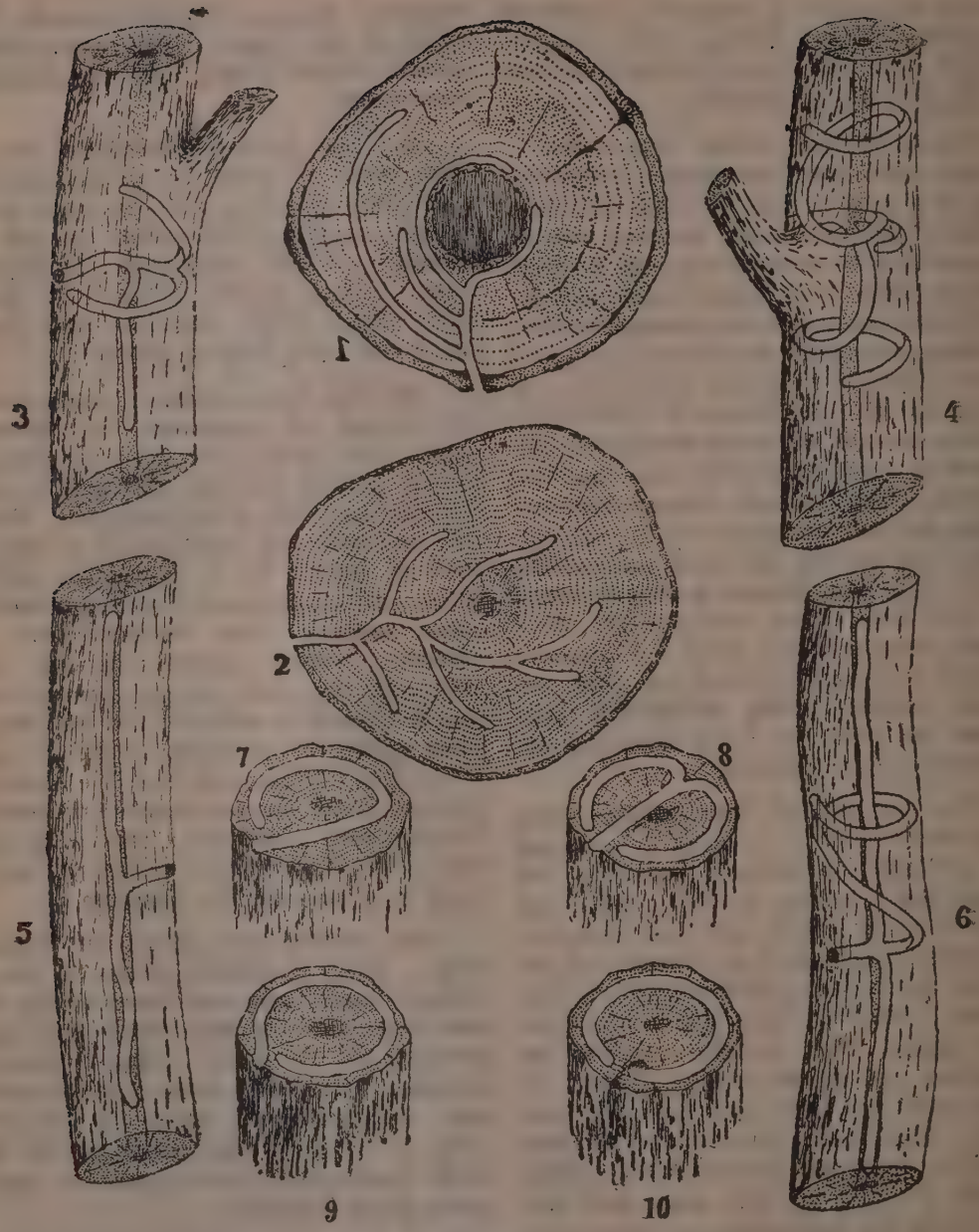

PLATE I

Galleries made by Shot-hole Borer (*Xyleborus fornicatus*)

1. In castor stem. 2. In large tea stem. 3—6. Longitudinal and spiral galleries in smaller tea stems. 7—10. Galleries at fractured ends of branches.

(Drawings by W. T. Fonseka.)

short of that gallery and never join it (Fig. 8). In fact, the beetle rarely (if ever) penetrates an existing gallery, no matter whether she or some other beetle made it. It is just as though she is aware of its existence and deliberately avoids penetrating it. (Figs. 7-10). Nor is the entrance gallery always driven through the middle of the stem. It often stops short soon after the wood is entered, and the beetle then turns either to the right or left and bores a circular gallery (Fig. 9), or the galleries may be spiral and more complex (Fig 4).

All tunnels are circular in section, and very uniform in diameter, just sufficiently large for the beetles to move easily along them. They are excavated by the female with her mandibles (jaws). The wood is cut into small strips about 0.6 mm. long and 0.2 mm. broad, *vide* Speyer, (1922), and the the fragments are thrown out of the gallery to form a small heap of wood dust below the entrance.

In thick castor branches the galleries of *X. fornicatus* follow the same plan in so far that they all start with a straight entrance gallery from which circular galleries following the curvature of the stem are made. (Fig 1). These are mainly in one plane and at varying distances from the pith ; rarely are they close to the cambium. The circular galleries first made start from the entrance gallery but later ones may start from existing circular galleries and run at different levels. The galleries in thick tea stems, presumably made by the tea borer, are somewhat different in that the side branches are not circular and they "ramify in a branching manner" as described by Green. (Fig. 2).

Instinct.—The construction of a gallery is a remarkable engineering feat. The whole procedure is, of course, instinctive but what controls the instinct is a matter for conjecture. From what has been said earlier it may appear that the thickness of the branch in which the beetle is boring largely determines the type or shape of the gallery to be made, but that cannot be entirely true. It may be convenient for an observer to classify galleries according to the diameter of the branch in which they are found, but such classification does not imply that the beetle also is aware of branch size. That would require an intelligence which the beetle cannot possess.

What seems more probable is that the beetle is able to perceive very keenly small changes in some character of the tissues through which she is boring and her response to that stimulus is to align her body relative to the direction of that change, much as a moth aligns its body to light rays falling on it, and so when flying is compelled to move towards the light source.

Gallery Position.—The positioning of the gallery is a matter of considerable importance to the beetle. Green (1903) clearly indicated his opinion on the subject as follows : "The object appears to be to check the flow of sap without absolutely stopping it, as the death of the branch would defeat the ends of the insect." The eggs are deposited in these circular galleries and the developing grubs feed upon the exudation of sap on the walls of the galleries and upon the delicate mycelium of a fungus that almost invariably clothes them." The idea here is that the gallery must be sited in a region sufficiently wet for the sap to exude into it in small quantities for the benefit of the young.

On physiological grounds there is no likelihood of an appreciable flow of sap into galleries. When a tea branch is pruned the cut surface never bleeds freely, and the exudation of sap from the cut is hardly more than sufficient to wet the surface for a very brief period. A pruning cut severs

all the water-conducting vessels, whereas a gallery severs, at most, a small fraction of them. Consequently exudation into a gallery is likely to be small and temporary.

Do galleries hinder the normal flow of sap, as Green suggested ? Direct evidence on this point is very difficult to obtain. If, however, every gallery caused a hindrance to the sap flow, though each hindrance is too small individually to cause any visible sign of its existence, the cumulative effect of numerous galleries in a heavily infested branch would surely become evident, and cause a wilt of at least some of the leaves. Heavily infested branches, however, have never given any indication of water shortage under normal conditions, nor are attacked bushes particularly susceptible to drought.

Whether the young feed on sap exuding on to the gallery wall is not proven, but it is certain that they eat "the delicate mycelium" and spores of the ambrosia fungus which invariably lines the walls. So far as is known the ambrosia fungus forms the main, if not the sole food supply of the beetles and their young. That the galleries must be sited where the fungus will grow well is, therefore, a matter of vital importance. Failure of the fungus means death for the beetles. It seems probable, therefore, that the galleries are sited so that the fungus may be planted where it will grow best, in the most 'fertile' part of the stem. The fungus requires nutrients for growth and these are most readily obtainable in the region of the cambium, and possibly, in parts of the pith.

In the writer's opinion the positioning of galleries is dependent largely upon the requirements for satisfactory growth of the fungus, necessary as food. That necessity is most likely to lead to the development of an instinct by natural selection. Beetles without that instinct (or with it only slightly developed) are likely to make galleries in unsuitable places and so fail to raise their young.

Exudation from Galleries.—Speyer (1922) was of the opinion that the exudation of sap into galleries is appreciable and that "Excess moisture in the wood during wet seasons drains out of the entrance hole in considerable quantities." Later in the same paper he states that the exudation is 'foul smelling.' Other observers give no support to Speyer's view that the gallery normally acts as a drainage channel. Exudations have occasionally been observed, but always under abnormal conditions. Rutherford (1914) commented on the exudation of a sour-smelling substance from galleries in which he found certain flies (Drosophilids). Jepson (1921) found galleries containing the flies and mentioned a 'putrid odour' but he made no reference to any fluid exudation. The writer has discussed these observations elsewhere (Gadd 1941a) and has put forward the view that the foul-smelling exudation is the result of a fermentation process which normally does not occur in galleries, and that the flies are attracted to it. He, therefore, regards the exudation as indicative of a 'diseased' condition of galleries.

Why Branches Break.—That borer infested tea branches should break is largely a matter of accident. The fracture is never solely due to the presence of a gallery : an external force must be applied to cause the branch to break. Whether a branch will break or not depends upon the following factors : (1) The diameter of the branch at the gallery (2) The type of gallery and (3) The pressure exerted to cause fracture.

One method of testing whether a tea bush is infested or not, is to sweep an arm over the bush so that pressure is exerted against the branches. This usually results in a number of fractures if the bush

is infested; the greater the pressure the greater the number of breakages. Very strong winds and most cultural operations which bring the labourers in contact with the bushes cause a certain amount of damage in infested fields. Plucking is perhaps the most important operation because it occurs most frequently.

Numerous measurements of branch diameter at the fracture have been made. The writer has published elsewhere (Gadd 1944) measurements made in 1942 and 1943. On six occasions in 1942 more than 5,000 branches were measured; none were less than one-eighth inch or more than five-eighth inch in diameter. Thirty-five per cent of them were between 2 and 3 eighths and 30 per cent between 3 and 4 eighths of an inch. These figures tell little more than the expected, viz. that the thinnest branches break most readily. Although any one branch is relatively small the cumulative damage to the bushes is often extensive.

King (unpublished data) had measured the diameters of 662 branches broken during plucking, and the galleries at the fractures classified according to their type. The great majority of the branches were again between two and three eighths of an inch in diameter. More than one third of the galleries at the fracture were circular without a long entrance gallery, as shown in Fig 9. Others were simple galleries with long entrances (Figs. 7 or 8), or were of more complex type. All had circular arms running in one transverse plane and not one was of the simple longitudinal type. The circular gallery was sometimes the terminal loop of a spiral which had been made in one plane (Fig. 10).

Breakages also occur during pruning. Tea wood is very hard and considerable force is necessary to sever sound branches even with a sharp knife. A branch breaking during pruning usually breaks below the place the knife cut is started. Consequently the branches broken during pruning are much thicker at the fractures than are branches broken during plucking. The types of gallery at the fractures, however, are much the same.

Other things being equal, ease of fracture will depend upon the amount of undamaged wood left after a gallery has been made. On that basis, galleries with a long entrance and two circular arms should break somewhat more easily than those with circular arms only. The data under consideration, however, cannot be used to prove or disprove this point, because no data are available of the relative numbers of each type actually made, only galleries at the fracture being recorded.

The addition of new wood by new growth after a gallery is completed must tend to strengthen the branch and decrease its liability to break.

Healing of Galleries.—"It will usually be found that galleries in the lower parts of the stem are unoccupied and that the exit (or entrance) holes have become obliterated by growth of new wood which completely shuts off the perforations. This blocking of the exit hole is of frequent occurrence in vigorous wood, and usually — though not invariably — results in the death of the contained insects." This quotation is taken from Green's important account of the shot-hole borer of tea (1903). It contains one rather glaring contradiction. In the first sentence he speaks of the galleries being "unoccupied" and in the last of "the death of the contained insects." A later passage, however, makes evident his opinion that beetles can be trapped and killed in their own galleries. "I have repeatedly observed that a vigorous condition of the plants results in an obliteration

of the earlier perforations and a tendency to choke out the insects that have more recently gained an entrance into the branches."

Speyer (1922) is somewhat more definite. He states "When the vigour of the cambial layer is sufficient to heal over a tunnel in process of construction, containing a single female beetle, the insect may sometimes have time to leave the tunnel, but often is entrapped and being unable to turn round in the tunnel, so as to force the entrance with its mandibles dies within it." This statement implies that the entrance to a gallery may be sealed up even before the gallery is completed, before eggs can be laid and a family raised. Green may have meant the same thing when he referred to "insects that have *more recently* gained an entrance."

The suggestion is that beetles may be trapped alive within the galleries. But why young females only should be so entombed is not obvious. Speyer's explanation that "normally at any rate, injury to the tissue is sufficient to prevent healing as long as the insects are developing in the gallery" does not help materially, as he leaves unexplained what injuries young developing insects can produce that adults, capable of boring through wood, cannot make.

In the writer's opinion both Green and Speyer have misinterpreted their observations. Jepson (1920) made somewhat similar observations and indicated the main difficulty of interpretation. He wrote "Instances have been found where female beetles occurred dead and imprisoned in a gallery completely healed, or in an advanced process of healing, but there is no evidence to indicate whether death had occurred before, or after, healing had commenced." Neither Green nor Speyer claim to have seen living beetles in a healed gallery. A dead female is often found within a healed gallery, but as a parent female is reputed to die in her gallery after her young have departed, the presence of her body in a healed gallery should not occasion surprise.

A matter which must have a bearing on the question whether beetles can be trapped alive is the time normally required for a gallery to heal. Before discussing that problem it seems advisable to consider the process by which galleries are healed.

Healing.—Enveloping the woody cylinder of a stem is a thin delicate tissue termed the cambium which by active cell division forms wood cells on its inner and cortical cells on its outer surface. Increase of a stem's diameter is due entirely to the activity of the cambium. The entrance tunnel of a gallery runs right through the cambium. That is the only injury inflicted on the cambium; it is small and does no appreciable harm. The cambium continues to divide and the stem to increase in thickness slowly. In addition, the cambium attempts to heal its wound by lateral outgrowths of cells, usually termed "callus." The callus from opposite edges of the wound ultimately meet and fuse together, and so form a plug in the gallery entrance. The cambium reforms in this tissue and again becomes an unbroken cylinder. In this way the wound becomes completely healed and the entrance to the gallery is sealed off. The obliteration of gallery entrances is therefore the normal process of healing, and consequently those with plugged entrances are termed 'healed' galleries.

The callus which plugs the entrance is much softer than wood, and a female beetle should have little or no difficulty in keeping the gallery entrance open. The beetle normally ejects wood fragments, etc. from the gallery by pushing them out with the

hind end of her body because she always faces inwards and cannot turn round. If she wishes, she can leave the gallery and so bring her mandibles into action to remove callus growth should that be necessary. Her body, particularly the thorax, is rough and might even be used as a rasp to remove callus at the entrance. Green even suggested that her rough body might be used in helping to excavate the tunnel. There does not, therefore, appear any reason why a beetle should be physically unable to prevent a slow growing, relatively soft tissue from blocking the gallery entrance as Speyer suggested.

Time for Healing.—Wounds on tea stems do not as a rule heal rapidly as compared with those of many other trees. Moreover there is a good deal of variation amongst tea bushes themselves as regards the rate at which their wounds will heal. It is not uncommon to find individual bushes with almost all their wounds partially healed while others immediately surrounding them give little evidence of healing. Such observations not only indicate that the rate of healing of gallery entrances varies from bush to bush, but they also throw doubt on the reliability of using healing as a measure of vigour.

Speyer's statement that a gallery entrance may become obliterated before the gallery can be completed suggests an extremely rapid rate of healing for tea, as a gallery may be made and eggs laid in so short a time as 10 days. Normally *vide* Speyer, entrances to galleries disappear almost entirely four months after pruning. This observation, however, must refer to galleries present in the frame at the time of pruning, but it clearly indicates that the plugging of galleries is not a rapid process.

King (1940) attempted to ascertain by direct observation the time elapsing between the formation and healing of galleries. His published data refer to 115 days' observation during which time only 16 per cent of the entrances (*i.e.*, 8 out of 49 galleries observed) healed. The shortest time observed was 36 days, but unfortunately no information is given regarding that gallery (and others), particularly as to whether it was occupied by the beetle or her young when healed. Beetles will sometimes begin a gallery and then desert it before completion. Such galleries would be expected to heal most rapidly because of the absence of a beetle to keep the entrance open. The data, however, show that the normal time of healing exceeds 115 days (or 4 months). In another experiment 500 new galleries were observed for various lengths of time but only 4 were observed to heal. The closing of these galleries occurred when they were 45, 59, 62 and 65 days old, respectively. These galleries were dissected and found to be empty, the parent females and their families (if any) having gone, evidently before the entrance was closed.

The writer has attempted to estimate the mean-time between gallery formation and healing by indirect methods. The first was based on Jepson's data (Gadd and Jepson 1926) and the second (Gadd 1941b) on data from another area collected during a plucking experiment. For details of the method used the original papers should be consulted. The first estimate gave from 3.2 to 4.3 months; the second was somewhat longer, viz. 20.1 weeks. These values are greater than the period which beetles and their young normally occupy galleries and indicate that entrances are not normally sealed off before the inmates leave the galleries.

These results give no support to the view that by rapid healing, beetles may be trapped within their galleries. They indicate a probability that the beetles can and do keep the entrances open as long as is

necessary. Healing, therefore, has no direct value in the control of shot-hole borer by limiting the time a gallery can be occupied by a female and her family.

Healing and Breakage.—Green was never "sanguine of finding a radical cure for this pest." His advice was summed up in the words "Keep the tree in a vigorous condition and it will fight its own battles, provided it is relieved from constant reinfection." How can the bush fight its own battles if it is unable to trap and kill the beetles invading its tissues? Jepson (1920) suggested an answer. He drew attention to the fact that in some fields the percentage of healed galleries is very high and gave a figure of 96.6 per cent. He regarded gallery occlusion or healing as a process by which "severely damaged branches could be completely restored to their former sound condition, weakened branches becoming so strengthened that they could not be fractured at the point where the stem had been invaded." These observations markedly influenced the direction of his later work, particularly his attempts to ascertain the value of manures in the control of this pest.

Does healing so strengthen a branch that it will not break at the place where a borer has invaded it? It has already been shown that the ease of fracture depends largely upon the diameter of the branch and the shape of the gallery in the branch. It seems preferable to alter the question to "Does the healing of a gallery strengthen the branch and so diminish its liability to fracture?" The data given in Table 1 will supply an answer to this question.

During 1945 and 1946 broken branches were collected weekly from certain experimental plots, last pruned in September, 1943, in the Passara district. The branches were collected and counted weekly, and on occasions, the galleries at the fracture were classified as healed or open. On these occasions all other galleries in the broken branches were counted and similarly recorded. The data given in Table I refer

TABLE I

Healing and Branch Fracture

	Galleries examined			Galleries at fracture			Unbroken Galleries		
		Healed			Healed			Healed	
	Total	No.	%	Total	No.	%	Total	No.	%
1945									
March 14	993	208	20·9	451	29	6·4	542	179	33·0
April 4	1161	198	17·1	602	37	6·2	559	161	28·8
April 25	1168	295	25·2	508	52	10·2	660	243	36·8
Total	3322	701	21·1	1561	118	7·6	1761	583	33·1
1946									
March 13	784	575	73·3	281	181	64·4	503	394	78·3
April 3	664	447	67·3	234	132	56·4	430	315	73·3
April 24	370	274	74·1	132	85	64·4	238	189	79·4
Total	1818	1296	71·3	647	398	61·5	1171	898	76·7

to three such occasions at 3-week intervals in 1945 and similar observations at the nearest corresponding date in 1946. On the three occasions in 1945, over three thousand galleries were examined of which 21.1 per cent had healed entrances. If all galleries are equally liable to result in fractures, no matter whether the gallery is healed or not, we should expect to find about 21 per cent of the galleries at the fractures to be healed. Instead, only 7.6 per cent of the galleries at the fractured ends of the branches were healed, whereas of the galleries at places which did not break 33.1 per cent were healed. On each occasion the results were similar and the observed differences (from expectation) are too large and too consistent to be due solely to chance.

During the corresponding weeks in 1946 the breakages in the same area were smaller in number, 647 as compared with 1,561 in 1945, but the percentage of healed galleries was greater. In this period 71.3 per cent of the galleries were healed as compared with 21.1 per cent in 1945, and again fewer healed galleries occurred at the fractures than would be expected if healed and open galleries were equally likely to cause breakage. We must, therefore, conclude that although healed galleries remain liable to break, they are less likely to fracture than galleries with open entrances.

Percentage of Healed Galleries.—Before leaving the data of Table I the question might be asked, Why was there a larger percentage of healed galleries in 1946, the third year from pruning, than in 1945, the second year from pruning? Was the process of healing speeded up during the third year? Or can other explanations be offered?

Jepson interpreted a high percentage of healed galleries as an indication that stimulation, or speeding up of the process had occurred. He wrote (Jepson 1920) "The greater percentage of healed galleries observed in the bushes which had been pruned, as compared with those which had been allowed to 'run up' appeared to indicate that this process of healing had been further stimulated by pruning." This line of reasoning prompted his work on the value of manures in shot-hole borer control. "If the process (healing) is not evident at all seasons but only following manuring, it will be important to discover the particular ingredient or element which assists the process."

There is, however, another interpretation of a high percentage of healed galleries which appears to have been overlooked. Let us suppose that for some reason or other, attack by beetles ceases altogether after a time. No new galleries would be formed, but the entrances of existing galleries would gradually become obliterated at the same rate as before the attack ceased. The percentage of healed galleries would consequently increase gradually to 100 when all entrances would be healed over. An increasing percentage of healed galleries may, therefore, mean a diminution or even a cessation of attack by the beetles. This question will be discussed in more detail when the measurement of attack is considered. For the present it is sufficient to show that the increased percentage of healed galleries in 1946 does not necessarily mean that healing was speeded up that year; it may, and in the writer's opinion does, suggest that the attack decreased, if it did not actually cease, in 1946, the third year from pruning.

Why Healed Galleries are less liable to Cause Breakages.—The mere presence of a callus plug in the entrance of a gallery cannot strengthen materially a branch at that point, so other reasons to account for the observed facts must be looked for. A

gallery with an open entrance may be of recent formation and contain a beetle and her young. It may, however, be somewhat older; the brood may have departed. A healed gallery is generally older still. The fact that a gallery entrance is obliterated is, therefore, an indication of its relative age.

The presence of galleries does not prevent a stem from growing in length or increasing in diameter. Whether a gallery entrance is open or closed is immaterial, the stem continues to increase in girth owing to the formation of new wood on the exterior of its woody cylinder. Other things being equal a healed gallery, merely because it has existed for a longer time, will have more new wood formed outside the gallery than a more recently formed gallery with an open entrance will have. The new wood gives added strength to the branch. Consequently healed galleries are less likely to result in fractures than are open galleries. It would perhaps be better to express the same idea in words relating to age and not to healing. *Old* galleries are less likely to lead to branch breakage than young galleries, other things being equal.

Manures and Healing.—Other things are not equal if a gallery in a vigorous bush is compared with another in an ill-nourished slow-growing bush. The simplest way of increasing the vigour or rate of growth of a bush is by suitable manuring. Consequently it would appear that by suitable manuring the time during which a bored branch is likely to break can be diminished. That in turn might lead to a reduction in the number of breakages occurring in a given area. Jepson held this opinion. He wrote (Jepson and Gadd 1926, p. 10), "One way of meeting the difficulty (breakages during plucking and other operations) is, therefore, to so improve the vigour of the bush as to induce the rapid healing over the gallery entrance holes and to lessen the tendency of the branches to break." He collected data concerning the healing of galleries from controlled experiments, and the present writer analysed the results. I then wrote (p. 47) "These experiments show that nitrogen, potash and phosphoric acid all tend individually to promote the healing of galleries."

The question the experiments did not answer, because no data was collected affecting it was "Does the use of manures reduce the loss of branches?" It was generally assumed that where healing is accelerated a reduction in loss of branches must follow as a natural consequence, but the question was not tested by direct experiment till much later, and the answer was surprising. The numbers of broken branches collected from experimental plots in 1945-46 (Gadd 1943, 1944a and b) were greatest in the plots giving the heaviest crops. Nitrogen caused the greatest increase in yield; it also caused the greatest increase in insect damage.

The effect of manures on breakages will be discussed more fully later. This section may, therefore, be terminated with the statement that, although manures increase the growth rate of bushes and accelerate the rate of healing of galleries, they do not diminish the damage as measured by the numbers of broken branches. Damage may increase as a consequence of their use.

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MINUTES OF A MEETING OF THE BOARD OF THE TEA RESEARCH INSTITUTE OF CEYLON HELD 6-9-46

Minutes of a Meeting of the Board of the Tea Research Institute of Ceylon held at the rooms of the Ceylon Tea Propaganda Board, Colombo, on Friday, September 6th, 1946, at 2-30 p.m.

Present.—The Chairman, Planters' Association of Ceylon (Mr. R. Singleton-Salmon), Acting Chairman; Mr. L. J. de S. Seneviratne, C.C.S. (Director of Agriculture) and Mr. H. E. Peries, C.C.S., representing the Financial Secretary, Messrs. J. C. Kelly, W. H. Attfield, F. Amarasuriya, E. G. Groves, F. A. Bond and Dr. R. V. Norris (Director and Secretary).

Apologies for absence were received from Mr. Spencer (Chairman, C. E. P. A.), Mr. H. S. Hurst and Mr. Wilkinson Kay.

(1). The Notice convening the Meeting was read.

(2). The Minutes of the Meeting of the Board held on the 21st June, 1946, were confirmed.

3. MEMBERSHIP OF THE BOARD AND COMMITTEES

(i) Board.—Reported that Mr. F. A. Bond had been appointed by the C. E. P. A. to act for Mr. D. T. Richards during the latter's absence on leave.

The Chairman welcomed Mr. Bond to the Board.

(ii) Finance Sub-Committee.—Mr. F. A. Bond was elected an acting member of the Finance Sub-Committee *vice* Mr. D. T. Richards.

4. FINANCE

(i) T. R. I. Accounts to the 31st July.—The Chairman, in presenting the accounts, pointed out that receipts to 31st July were Rs. 40,209 above those to the same date in 1945. This was due to an increase in the yield from the Cess of Rs. 33,767 and higher receipts from tea sales. On Estate Working Account, the figure showed a profit to 31st July of Rs. 6,594 as against a debit of Rs. 20,331 in the previous year. 31,945 lb. manufactured tea were awaiting sale. Referring to current account, the Chairman said the amount might seem high but there

were considerable commitments to be met in the near future.

The accounts were approved.

(ii) Additional Vote.—An additional grant of Rs. 2,000 was sanctioned under Vote 33A, Field Experiments, Plant Physiologist.

5. ST. COOMBS ESTATE

(1) *Crop.*—Reported that the crop to 31st July at 160,150 lb. showed an increase of 35,237 lb. over 1945. No difficulty was anticipated in reaching the estimate and this might be exceeded if favourable weather obtained in the last four months of the year. August with 15.47 inches of rain falling on 28 days, had been the wettest part of the year.

(ii) Sprinklers.—In reply to Mr. Kelly, the Director said that all material for this installation had arrived and there seemed a reasonable chance the work might be completed in the near future.

(iii) Mr. J. A. Rogers.—The Director informed the Board that Mr. Rogers had asked him to convey his very deep appreciation of the provision made for him by the Board on his recent retirement.

(iv) New Superintendent.—The Chairman asked the Board to decide on the arrangements to be made in regard to the appointment of a permanent Superintendent for St. Coombs. It was decided that the post be advertised and that the Chairman, Visiting Agent and the Director be empowered to select the person considered most suitable, and to define his duties and terms of service, and within the salary scale already approved (Rs. 750-50-1250 plus Dearness Allowance, plus four labour allowances, with Provident Fund contribution at 10 per cent).

In regard to the new Superintendent's duties, the Board agreed that he should in addition to ordinary estate matters, be responsible for all buildings, research and estate, and public services such as water and electricity supplies and upkeep of grounds. In addition he would be expected to give all assistance required in the experimental programme of the Institute and take over such advisory work to outside estates as might be allocated to him by the Director.

(v) Visiting Agent's Report dated the 10th July, 1946.—The above report was accepted and recorded after the Director had replied to one or two comments.

6. DIRECTOR

The Board sanctioned the application by the Director for 7½ months' leave out of Ceylon. It was agreed the Director might hand over charge at the middle of the month but that the leave would count as from the date his ship sailed.

The following consequential arrangements were then approved :—

(a) Dr. C. H. Gadd, Deputy Director, to act as Director in addition to his own duties as Entomologist, and to receive an acting allowance of Rs. 400 per mensem.

(b) Dr. F. R. Tubbs to act as Mycologist in addition to his own duties pending the arrival of a Mycologist.

(c) Dr. T. Eden to take over the supervision of the Biochemical Department in addition to his own duties, pending the return of Mr. Lamb about the end of November.

In regard to (b) and (c) it was agreed that acting allowances of Rs. 150 per mensem be given.

7. SENIOR SCIENTIFIC STAFF

(i) Mycologist.—Reported that no suitable person had yet been obtained to fill the

vacancy. One gentleman had actually been selected but had later withdrawn his name. Another applicant had been considered but, in view of the fact that he would only be likely to remain about five years in Ceylon, his appointment could not be recommended. In these circumstances, the post was being readvertised.

(ii) Scientific Officer.—Reported that the second vacancy, caused by the resignation of Mr. King, had been advertised. The advertisement called for an officer with experience in general agriculture and soil management and a knowledge of field experimental work. Professor Engledow had been asked to assist, with the co-operation of Sir John Russell, in obtaining a suitably qualified officer.

In view of the difficulty which now exists, and is likely to remain, in the recruitment of senior technical officers, the Board directed that in the event of any further vacancy appearing likely, preliminary enquiries should at once be made as regard filling that vacancy without necessarily waiting for any such resignation to become effective.

8. JUNIOR SCIENTIFIC STAFF

The Board approved the appointment of Mr. S. N. Vander Wal as Assistant in the Mycological Division on the normal salary scale of the post.

9. NEW BUILDINGS

The Chairman reported that firm estimates had not yet been received for the three new Junior Staff bungalows but the cost was not likely to deviate materially from the provisional figure approved by the Board.

The final figures would be submitted to the Buildings Committee to whom the Board had already given power of sanction.

10. JUNIOR STAFF PROVIDENT FUND

Reported that a letter had been received from the Minister for Agriculture and Lands, intimating that the Attorney-General was of opinion that the Institute had no power to run a Provident Fund for its Junior Staff and suggesting that legislative action to secure such powers might be necessary.

In reply it had been pointed out to the Minister that the Junior Staff Provident Fund was not controlled by the Board but by separate Trustees of whom only two were members of the Board. This fact might remove any necessity for legislation, but a final ruling on this point had not been received from the Attorney-General.

11. JOINT RESEARCH ON THE CHEMISTRY OF TEA

Reported that a letter had been received from the Ceylon Association intimating that the joint work on the chemistry of tea, which had been suspended in 1944, was now being resumed. The Institute had been asked to renew the contribution formerly made of £375 per annum and, if possible, increase this. The Board had already expressed the hope that the work would be resumed and the Director suggested that, pending receipt of further details as to how the work was to be supervised and an estimate of the total cost obtained, the Board should resume its *former* rate of contribution with effect from 1st July, 1946. When full details were available, the question of any increased contribution could be further considered. The Board approved of this being done.

12. ANY OTHER BUSINESS

In reply to Mr. Kelly, the Director said the address recently given by Mr. Lamb to the Ceylon Association would be published in Part III of the *Tea Quarterly*.

The Meeting then terminated with a vote of thanks to the Chair.

ROLAND V. NORRIS,
Secretary.

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The Tea Research Institute of Ceylon.

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(12) The Chairman, Ceylon Estates Proprietary Association.

Acting Secretary, C. H. Gadd, D.Sc., St. Coombs, Talawakelle.

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